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ABSTRACT:

A method and apparatus for conducting a pilot signal search in a **wireless** communications network. The location of a **mobile** is determined within the network. This location is then used in determining search window sizes and other search parameter information that is used to search all pilot signals identified in a designated pilot signal set. Search window size is also determined based upon the location of the **mobile** and another component related
to multipath effects for a transmitted pilot signal.

BRIEF SUMMARY:

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to communications. More particularly, the invention concerns a method and apparatus for reducing search times associated
with the handoff of a call from one base station to another base station.

[0003] 2. Description of the Background Art

[0004] **Wireless** communication systems generally comprise, amongst other elements, a **wireless** unit, commonly referred to as a **mobile** telephone (**mobile**),
that communicates with one or more base stations when making a call. The **mobile** communicates with the base stations on one or more channels that are contained within a frequency band assigned to the **mobile** by a base station controller. A communication from the **mobile** to a base station is made on what is called the "reverse link," and a communication from the base station to the **mobile** station is made on the "forward link." During a call, the **mobile** station is constantly searching for other base stations that the **mobile** might need to continue the call while the **mobile** station is moving around.

[0005] One important element of a **mobile** used in such a **wireless** system is the searcher. The **searcher is programmed to search for pilot** signals (pilots) transmitted from different bases stations in at least three cases: 1) when a **mobile** is trying to acquire a base station for communication; 2) in the idle state when the **mobile** is on the paging or access channels; and 3) in the traffic state where the **mobile** is in control of the traffic channel. The speed of **searching the pilots** on the frequency assigned to the **mobile** and other frequencies determines the search performance of the **mobile**. In slotted mode,

the objective is to **search all pilots** in the neighbor set before the slot expires. Slotted mode refers to an operation mode of the **mobile where the mobile** monitors only during selected slots of **time**. Also, when **searching pilots** in a "candidate" frequency, the **mobile** needs to complete its **search of all pilots** in the candidate set as quickly as possible so that it tunes back to the serving frequency and minimizes the voice degradation caused by searching the candidate frequency. As discussed below, the candidate frequency is a potential handoff frequency, and these searching techniques are used to coordinate handoffs of communications in the **wireless** communication system.

[0006] A. Handoffs

[0007] A **mobile** used in a code-division-multiple-access (CDMA) **wireless** system
supports three types of handoff procedures when the **mobile** is in control of the traffic channel. The use of CDMA techniques in a multiple access communication
system is disclosed in U.S. Pat. No. 4,901,307, issued Feb. 13, 1990 and entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE
OR TERRESTRIAL REPEATERS," assigned to the assignee of the present invention
and incorporated by reference herein. The three types of handoffs are:

[0008] 1. Soft Handoff--A handoff in which the **mobile** commences communications
with a new base station without interrupting communications with the old base station. Soft handoff can only be used between CDMA channels having identical
frequency assignments.

[0009] 2. CDMA to CDMA Hard Handoff--A handoff in which the **mobile** is transitioned between disjoint sets of base stations, different band classes, different frequency assignments, or different frame offsets.

[0010] 3. CDMA to Analog Handoff--A handoff in which the **mobile** is directed from a cdma forward traffic channel to an analog voice channel.

[0011] To perform soft handoff, the **mobile** continuously searches for assigned sets of pilots. The term "pilot" refers to a pilot channel identified by a pilot sequence offset and a frequency assignment. A pilot is associated with the forward link traffic channels in the same forward link CDMA channel, or similarly with the reverse link on systems using reverse link pilots. All

pilots in a pilot set have the same CDMA frequency assignment. For clarity, pilots are discussed in terms of the forward link only.

[0012] The **mobile** searches for pilots on the current CDMA frequency assignment
to detect the presence of CDMA channels and to measure their signal strength. When the **mobile** detects a pilot of sufficient strength that is not associated with any of the forward link traffic channels already assigned to it, it sends a pilot strength measurement message to the base station with which it is currently communicating. The base station can then assign a forward link traffic channel associated with that pilot to the **mobile** and direct the **mobile** to perform a handoff.

[0013] The pilot search parameters and the rules for pilot strength measurement message transmission are expressed in terms of the following sets of pilots:

[0014] Active Set: The pilots associated with the Forward Link Traffic Channels assigned to the **mobile**.

[0015] Candidate Set: The pilots that are not currently in the Active Set but have been received by the **mobile** with sufficient strength to indicate that the associated Forward Link Traffic Channels could be successfully demodulated.

[0016] Neighbor Set: The pilots that are not currently in the Active Set or the Candidate Set and are likely candidates for handoff.

[0017] Remaining Set: The set of all possible pilots in the current system on the current CDMA frequency assignment, excluding the pilots in the Neighbor Set, the Candidate Set, and the Active Set. This set of possible pilots consists of pilots whose pilot PN sequence offset indices are integer multiples of some pilot increment.

[0018] The base station may direct the **mobile** to search for pilots on a different CDMA frequency to detect the presence of CDMA channels and to measure
their strengths. The **mobile** reports the results of the search to the base station. Depending upon the pilot strength measurements, the base station can direct the **mobile** to perform an inter-frequency hard handoff.

[0019] The pilot search parameters are expressed in terms of the following sets of pilots:

[0020] Candidate Frequency Neighbor Set: A list of pilots on the CDMA

Candidate
Frequency.

[0021] Candidate Frequency Search Set: A subset of the Candidate Frequency Neighbor Set that the base station may direct the **mobile** to search.

[0022] B. Pilot Search

[0023] In current systems, the base station sets the search window, that is, the range of PN offsets, in which the **mobile** is to search for usable multipath components. These multipath components are used by the **mobile** for demodulation
of an associated forward link traffic channel. Search performance criteria, and general **wireless** system criteria, are defined in standards TIA/EIA-95x and TIA/EIA-98-B, all issued by the Telecommunications Industry Association, and ANSI J-STD-018, issued by the American National Standards Institute, all of which are incorporated by reference herein. These searches are generally governed by the following:

[0024] Active Set and Candidate Set: The search procedures for pilots in the active and candidate sets are identical. The search window size for each pilot in the active and candidate sets is the number of PN chips specified in Table 1 corresponding to SRCH_WIN_A. For example, SRCH_WIN_A.sub.S=6 corresponds to a
28 PN chip search window or .+-.14 PN chips around the search window center. The **mobile** station centers the search window for each pilot of the active and candidate sets around the earliest arriving usable multipath component of the pilot.

1TABLE 1 SRCH_WIN_A SRCH_WIN_A SRCH_WIN_N SRCH_WIN_N Window SRCH_WIN_NGHB
Window SRCH_WIN_NGHB Size R SRCH_WIN_R Size R SRCH_WIN_R (PN CF_SRCH_WIN_N
(PN Chips) CF_SRCH_WIN_N Chips) 0 4 8 60 1 6 9 80 2 8 10 100 3 10 11 130
4 14 12 160 5 20 13 226 6 28 14 320 7 40 15 452

[0025] Neighbor Set: If a flag for a different neighbor search window is set, the **search window size for each pilot** in the neighbor set is the number of PN chips specified in Table 1, corresponding to search window size parameter associated with the **pilot being searched**. If the flag is not set, the **search window size for each pilot** in the neighbor set is the same and is equal to the number of PN chips specified in Table 1 corresponding to SRCH_WIN_N.sub.S.

The
mobile centers the **search window for each pilot** in the neighbor set around the
pilot's PN sequence offset, using **timing** defined by the **mobile's time** reference.

[0026] Remaining Set: The **search window size for each pilot** in the remaining set is the number of PN chips specified in Table 1 corresponding to SRCH_WIN_R.sub.S. The **mobile** centers the **search window for each pilot** in the
remaining set around the pilot's PN sequence offset, using **timing** defined by the **mobile's time** reference. The **mobile searches for remaining set pilots** whose pilot PN sequence offset indices are equal to integer multiples of the pilot increment.

[0027] Candidate Frequency Search Set: If the flag for candidate frequency is set, the **search window size for each pilot in the candidate frequency search**
shall be the number of PN chips specified in Table 1, corresponding to SRCH_WIN_NGHBR associated with the **pilot being searched**. If the flag is not
set, the **search window size for each pilot in the candidate frequency search**
set shall be the number of PN chips specified in Table 1 corresponding to CF_SRCH_WIN_N. The **mobile** centers the **search window for each pilot in the**
Candidate Frequency Search Set around the pilot's PN sequence offset using
timing defined by the **mobile's time** reference.

[0028] C. Time to Search

[0029] Each phone manufacturer has its own way of implementing a search strategy. In all strategies, the **time to search a specific pilot** depends on the window size and the hardware of the searcher. Given certain hardware, the **time to search a pilot is linearly proportional to the search** window size. Reducing the search window size will result in a substantial reduction in searching **time**. Using current searching procedures, the window sizes are mostly determined by the size of the coverage area of a given cell. A cell is the geographical area covered by a base station for communication with a **mobile**. Four such cells are shown in FIG. 1. Regardless of the location of the **mobile** in the serving cell, current search windows are sized to correspond

to the worst case scenarios. That is, they are sized to correspond to a **mobile** located at the greatest distance from the base station but within the cell.

[0030] On the paging or traffic channels, the **mobile** centers its **search window for each pilot** in the neighbor set around the pilot's PN sequence offset, using **timing** established by the **mobile's time** reference. The **mobile's time** reference
is defined as the earliest arrived and usable path. The worst case scenario determines the search window size. For example, FIG. 1 shows four adjacent cells 102, 104, 106, and 108 in a **wireless** system 100, each having a pilot designated PN1, PN2, PN3, and PN4, respectively. The **search window size for**
pilot PN1 is determined based on a **mobile** located at point A. However, the same
search window is used even if the **mobile** is at point B. This results in a waste of valuable searcher resources since it does not consider the location of the **mobile** within cell 104. If the **mobile** is at point B, the search window should be reduced in size relative to the search window required for a **mobile** located at point A.

[0031] D. Location Methods

[0032] Many techniques are being considered to provide for automatic location capability for **mobiles**. One technique involves measuring the time difference of arrival of signals from a number of cell sites. These signals are "triangulated" to extract location information. This technique requires a high concentration of cell sites and/or an increase in the transmission power of the sites to be effective because typical CDMA systems require each **mobile** to transmit with only enough signal power to reach the closest cell site. This triangulation requires communication with at least three sites, requiring an increase in the concentration of cell sites or the signal power of each **mobile** station would have to be increased. Another approach involves the addition of GPS (Global Positioning System) functionality to a **mobile**. This approach requires a line-of-sight to four satellites, is somewhat slow, but is the most accurate approach for locating a **mobile**.

[0033] A third approach sends aiding information to the **mobile** indicating in which frequency range the **mobile** should look for a GPS carrier. Most GPS receivers use what is known as a GPS satellite almanac to minimize a search performed by the receiver in the frequency domain for a signal from a visible satellite. The almanac is a 15,000 bit block of coarse ephemeris and time model data for the entire constellation. The information in the almanac regarding the position of the satellite and the current time of day is

approximate only. Without an almanac, the GPS receiver must conduct the widest
possible frequency search to acquire a satellite signal. Additional processing is required to attain additional information that will aid in acquiring other satellites. The signal acquisition process can take several minutes due to the large number of frequency bins that need to be searched. Each frequency bin has a center frequency and predefined width. The availability of the almanac reduces the uncertainty in satellite Doppler and therefore the number of bins that must be searched. The satellite almanac can be extracted from the GPS navigation message or sent on the down forward link from the satellite to the **mobile** as a data or signaling message. On receipt of this information, the **mobile** performs GPS signal processing to determine its location.

[0034] What is needed is a method and apparatus can use the location information for a **mobile** in conjunction with pilot search techniques to improve the speed by which a **mobile** can search all pilots on an assigned frequency while the **mobile** is in control of the traffic channel. The invention should be able to utilize information about the physical location of the **mobile** to determine the search window size for each pilot in the neighbor and candidate sets.

SUMMARY OF THE INVENTION

[0035] Broadly, the invention relates to a communication network. More specifically, the invention relates to an apparatus and method that utilizes the position of a **mobile** in determining the search window size for a pilot in the neighbor and active candidate sets.

[0036] One embodiment of the invention provides a method for conducting a pilot
signal search in a **wireless** communications network. First, the location of a **mobile** is determined within the network. This location is then used in determining search window sizes and search parameter information used to search
all pilots identified in a pilot set. Search window size is also determined based upon the location of the **mobile** and another component related to multipath effects for a transmitted pilot signal.

[0037] In another embodiment, the invention provides an article of manufacture containing digital information executable by a digital signal processing unit and used to conduct a **pilot signal search in a wireless** communications network.
In another embodiment, the invention yields an apparatus used to conduct the

pilot signal search. In one embodiment, the apparatus comprises at least one base station, wherein each base station transmits a pilot signal, and wherein the base station is used to determine the location of a **mobile** within the communications network. The apparatus may also include at least one **mobile, wherein a mobile** is communicatively coupled with at least one base station, and
wherein the **mobile** uses search window sizes and other search parameter information transmitted to it to minimize the **search time required for searching all pilot** signals associated with a selected pilot set.

[0038] The invention provides its users with numerous advantages. One advantage is that the **time** required to **search a set of pilot** signals is reduced over known techniques. Another advantage is that valuable searcher resources are not wasted because a more efficient search may be conducted. The invention
also provides a number of other advantages and benefits that should become apparent after reviewing the following detailed description of the invention.

DRAWING DESCRIPTION:

BRIEF DESCRIPTION OF THE DRAWING

[0039] The nature, objects, and advantages of the invention will become more apparent to those skilled in the art after considering the following detailed description in connection with the accompanying drawings, in which like reference numerals designate like parts throughout, and wherein:

[0040] FIG. 1 shows four adjacent cells in a **wireless** communication system in accordance with the invention;

[0041] FIG. 2a illustrates a **wireless** communications apparatus utilizing a satellite positioning system in accordance with the invention;

[0042] FIG. 2b shows a **wireless** communications network in accordance with the
invention;

[0043] FIG. 3 shows a block diagram of a **mobile** in accordance with the invention; and

[0044] FIG. 4 illustrates an exemplary example of an article of manufacture in

accordance with the invention.

DETAILED DESCRIPTION:

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0045] FIGS. 2a-4 illustrate examples of various method and apparatus aspects of the present invention. For ease of explanation, but without any limitation intended, these examples are described in the context of a digital signal processing apparatus. The digital signal processing apparatus used to execute a sequence of machine-readable instructions as referred to above may be embodied by various hardware components and interconnections. Various arrangements for these digital signal-processing apparatuses will become apparent to anyone schooled in the art after reading the below description of the methods involved.

Operation

[0046] The aforementioned patents and publications all describe a pilot signal used for acquisition. The use of a pilot signal enables the **mobile** to acquire a local base station in a timely manner. The **mobile** gets synchronization information, including a psuedorandom noise (PN) code phase offset, and relative signal power information from a received pilot signal carried on a pilot channel. Once a pilot channel has been acquired, the **mobile** may also acquire a synchronization channel (sync channel) that is associated with the pilot channel. The sync channel is used to receive fine-tuning of its timing instructions and thereby permit the **mobile** to temporally synchronize its internal circuitry with system time. It can be appreciated in light of the above discussion that it is important that the internal time of the **mobile** be synchronized with the system time. This enables the **mobile** to know where in the PN code sequence the base station is and enables communication between the
base station and the **mobile**. Accordingly, when the **mobile** is in communication with a base station, the base station transmits system time to the **mobile** to facilitate synchronization.

[0047] In a spread spectrum communication system, a pilot signal is used to synchronize a **mobile** station in phase and frequency to the transmissions of a base station. In the exemplary embodiment, the spread spectrum communication
system is a direct-sequence spread spectrum communication system. Examples

of
such systems are discussed in U.S. Pat. No. 5,056,109, issued Mar. 3, 1992, entitled "METHOD AND APPARATUS FOR CONTROLLING TRANSMISSION POWER IN A CDMA
MOBILE TELEPHONE SYSTEM," and U.S. Pat. No. 5,103,459, issued Apr. 7, 1992,
entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA **CELLULAR**
TELEPHONE SYSTEM," both of which are assigned to the assignee of the present
invention and incorporated by reference herein. In a direct-sequence spread spectrum communication system, the transmitted signals are spread over a frequency band greater than the minimum bandwidth necessary to transmit the information by modulating a carrier wave by the data signal, then modulating the resulting signal again with a wideband spreading signal. In a pilot signal of one embodiment, the data can be looked at as an all ones sequence. A linear feedback shift register, the implementation of which is described in detail in the aforementioned patents, typically generates the spreading signal. The spreading signal can be viewed as a rotating phasor of the form:

s(t)=Ae.sup.-.omega.t+.phi.

[0048] In order to acquire a base station, a **mobile** must synchronize to the received signals from the base station in both phase, .phi., and in frequency, .omega.. A searcher finds the phase of the received signal, .phi.. After finding the phase of the spreading signal, .phi., the frequency is found by using a demodulation element that has hardware for both phase and frequency tracking. The method by which the **mobile** finds the phase of the received signal is by testing a set of phase hypotheses, discussed in terms of the search window above, and determines if one of the hypothetical phase hypotheses, also referred to as offset hypotheses, is correct. An example of a searcher operating using "window" searches is given in copending U.S. Pat. No. 5,805,648, filed Sep. 8, 1998 and entitled "METHOD AND APPARATUS FOR
PERFORMING SEARCH ACQUISITION IN A CDMA COMMUNICATION SYSTEM," assigned to the
assignee of the present invention and incorporated herein by reference.

[0049] To allow for the handoff of a call, the **wireless** system uses so-called "slotted" searching. In other words, a **mobile** performing slotted searching is assigned periodic windows (referred to as "slots") to search for other bases stations to which it might handoff a call. Accordingly, **mobiles search for pilot** channel signals transmitted by surrounding bases stations in a

predetermined window centered about the location in the PN code sequence at which the **mobile** expects the pilot channel to be, in accordance with standards set forth above. The base station that the **mobile** is currently communicating may send a search window size and other parameters, such as system **time, to the**
mobile. As the skilled artisan will readily appreciate, this reacquisition search window should be small as possible to avoid prolonged searching, but sufficiently large enough to account for typical internal clock errors.
Further, the search parameters should be as particularized as possible.

[0050] In an exemplary embodiment, the present invention may reduce the search
window size for PN1 shown in FIG. 1 by relative to currently known standard methods. As shown in FIG. 1, where the location of the **mobile** station is known to be within a circle of radius r, a search may be centered around d1-d2 with a search size of .+-.2r. A typical value for "r" is 100 meters. In this example, a circle is used to represent any "position uncertainty" region for a **mobile**. However, ellipses, squares, and rectangles may also be used to represent these "position uncertainty" regions.

[0051] Further, if the **mobile** is at point C, the search window for PN1 could be reduced by a factor of 3R/4r, where R is the radius of the cell and r is the radius of the location uncertainty region. In one embodiment, the invention accomplishes this by using the physical location of the **mobile** to particularize the search window size. In another embodiment, the invention uses the location to particularize all of the search parameters.

[0052] To perform the method, the approximate location of the **mobile** must be known. This location may be determined in various ways known in the art and mentioned above. A discussion of one exemplary **mobile** location determination technique is discussed in co-pending U.S. patent application Ser. No. 09/040,501 entitled "SYSTEM AND METHOD FOR DETERMINING THE POSITION OF A
WIRELESS CDMA TRANSCEIVER," filed Mar. 17, 1998, assigned to the assignee of
the present invention and incorporated by reference herein. For purposes of the present invention, a precise position determination is not necessary. Course techniques may be used to determine the **mobile's** location.

[0053] Once the **mobile** is in control of a traffic channel, the base station that is currently handling the communication transmits a message telling the **mobile** the size of the search windows to be used for searching for the pilot signals contained in the neighbor set. The search window sizes are determined

considering the **mobile** location within the serving cell. For example, and referring to Table 1 and FIG. 1, the search window for PN1 may be reduced from 12 to 4, reducing the window size from 160 chips to 14 chips, for a **mobile** located at position B. And because the search window size is reduced, demodulation expenses are reduced, and searches are completed expeditiously.

[0054] The searcher window size has at least two components, one component related to the geometric distance between the phone and the targeted pilot, and another related to multipath effects for a transmitted pilot signal. Accordingly, combining the effects of the two components minimizes selected search window size. In CDMA systems, space or path diversity is obtained by providing multiple signal paths through simultaneous links from a **mobile** through two or more cell-sites. Furthermore, path diversity may be obtained by exploiting the multipath environment through spread spectrum processing by allowing a signal arriving with different propagation delays to be received and processed separately. Examples of path diversity are illustrated in U.S. Pat. No. 5,101,501, issued Mar. 31, 1992, entitled "SOFT HANDOFF IN A CDMA **CELLULAR** TELEPHONE SYSTEM", and U.S. Pat. No. 5,109,390, issued Apr. 28, 1992, entitled "DIVERSITY RECEIVER IN A CDMA **CELLULAR** TELEPHONE SYSTEM", both assigned to the assignee of the present invention and incorporated by reference herein.

[0055] In another embodiment, the search parameters may also be chosen based upon the location of the **mobile**. When the **mobile** is in control of the traffic channel, a base station will transmit search parameters to the **mobile**. These search parameters utilize knowledge of the location of the **mobile** to particularize or "customize" the search parameters. This particularizing is used to optimize searcher procedures. Optimizing search window size and the procedures used by the searcher to perform the search results in reduced search times.

[0056] In yet another embodiment, once the window size has been determined corresponding to geographical areas in a cell, the window sizes are stored in a memory unit. Searcher procedure parameters may also be stored. Assuming that the cells in the **wireless** system remain substantially unchanged, these window sizes may be communicated to and used by any **mobile** that is located within the geographical area. The base station controller, knowing the location of a

mobile, can look up the window size and/or the searcher procedure parameters and transmit them to the **mobile**. In another embodiment, the **mobile** may store the information.

Apparatus Components and Interconnections

[0057] Various apparatus embodiments are discussed below in relation to particular **mobile** location systems and supporting hardware embodiments. However, those schooled in the art will recognize that various location systems may be used.

[0058] FIG. 2(a) is a diagram showing an implementation of a base station 202 and a **mobile** 204 in a synchronous CDMA communication network. The network is
surrounded by buildings 206 and ground based obstacles 208. Base station 202 and **mobile** 204 are disposed in a GPS environment having several GPS satellites,
of which four are shown 210, 212, 214 and 216. Such GPS environments are well
known; for example, see for example Hofmann-Wellenhof, B., et al., GPS Theory and Practice, Second Edition, New York, N.Y.: Springer-Verlag Wien, 1993. In a typical prior art GPS application, at least four satellites are required in order for a GPS receiver to determine its position. In contrast, the position of the remote station 204 may be determined using signals from as few as one GPS satellite and, in the simplest case, two other terrestrial based signals.

[0059] FIG. 2(b) shows a block diagram of a CDMA network 220. The network 220
includes a **mobile** switching center (MSC) 222 having a base station controller (BSC) 224. A public switched telephone network (PSTN) 226 routes calls from traditional terrestrial based telephone lines and other networks (not shown) to and from MSC 222. MSC 222 routes calls from PSTN 226 to and from a source base
station 228 associated with a first cell 230 and a target base station 232 associated with a second cell 234. In addition, MSC 222 routes calls between the base stations 228 and 232. The source base station 228 directs calls to the first **mobile** 236 within the first cell 230 via a first communications path 238. The first communications path 238 is a two-way link having a forward link 240 and a reverse link 242. Typically, when the base station 228 has established communications with the **mobile** 236, the forward link 240 includes a
traffic channel.

[0060] A **wireless** positioning function (WPF) 242 is shown communicatively coupled to BSC 224, but may be coupled directly or in-directly to other network elements such as MSC 222. WPF 242 generally comprises a digital processing device, storage, and other elements (all not shown) commonly found in such devices. WPF 242 may be put to a variety of uses, such as estimating the one-way time delay for a signal sent between the base station 228 and the **mobile** 236, or monitoring and accounting for the time offset between a reference time and a time of arrival of a signal.

[0061] Although each base station 228 and 232 is associated with only one cell, a base station controller often governs or is associated with base stations in several cells. When **mobile** 236 moves from first cell 230 to second cell 234, **mobile** 236 begins communicating with the base station associated with the second cell. This is commonly referred to as a "hand-off" to target base station 232. In a "soft" handoff, **mobile** 236 establishes a second communications link 244 with target base station 232 in addition to first communications link 238 with source base station 228. After **mobile** 236 crosses
into second cell 234 and the channels with the second cell has been established, the remote station may drop first communications link 238.

[0062] In a hard handoff, the operation of source base station 228 and target base station 232 typically are different enough that communications link 244 between the source base station must be dropped before the link to the target base station can be established. For example, when a source base station is within a CDMA system using a first frequency band and target base station is in a second CDMA system using a second frequency band, the remote station will not
be able to maintain links to both base stations concurrently, since most remote stations do not have the ability to tune to two different frequency bands concurrently. When first **mobile** 236 moves from the first cell 230 to second cell 234, link 238 to source base station 228 is dropped and a new link is formed with target base station 232.

[0063] Turning to FIG. 3, a **mobile** 300 is shown in **wireless** communication with a base station 302 of a **wireless** communication system, generally designated 304. It is to be understood that although a single base station 302 and a single **mobile** 300 are shown in FIG. 3 for clarity of disclosure, the system 304 would typically include other **mobiles** and base stations (not shown). In an exemplary embodiment, the system 304 implements code division multiple access
(CDMA) principles to discriminate one **mobile** signal from another. Details of a preferred CDMA system are set forth in the above referenced U.S. Pat. No.

4,901,307, issued Feb. 13, 1990 and entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS," assigned to the assignee of the present invention and incorporated by reference herein. As shown in the figure, **mobile** 300 includes a receiver/transmitter 306 that can communicate with base station 302 via a **wireless** link 308. Further, **mobile** 300 includes control circuitry for controlling the reception and transmission of data by receiver/transmitter 306. In FIG. 3, this control circuitry is rendered, for simplicity, as a digital signal processor 310. As also shown, processor 310 can access a data storage device 312. Although not shown, base station 302 may also house digital signal processing equipment and storage. As more fully disclosed below, data storage device 312 contains instructions that are executable by the digital signal processor 310. Accordingly, with the exception of the logical structure of data storage device 312, **mobile** 300 preferably is a CDMA **mobile** as is known in the art.

[0064] Additionally, **mobile** 300 includes an internal clock 314. In one embodiment, internal clock 314 is a voltage controlled temperature controlled crystal oscillator (VCTCXO). However, it should be noted that other clock devices, whether or not crystal-based, are equally suitable for use with the present invention. Accordingly, the output signal of clock 314 is a sequence of clocking pulses that are sent to a counter 316, with the rate of clocking pulse output being controlled by controlling the voltage of an input signal to clock 314 from a clock power supply 318 in accordance with well-known principles. Clock 314 may be synchronized with system time by the receipt of a timing message from base station 302 as discussed above.

[0065] Article of Manufacture

[0066] The methods as described above may be implemented, for example, by operating a digital signal processing unit to execute a sequence of machine-readable instructions. These instructions may reside in various types of signal bearing media. In this respect, one aspect of the present invention concerns an article of manufacture comprising a signal bearing media tangible embodying a program of machine-readable instructions executable by a digital signal processing unit to perform a method to reduce the **time** needed to perform a **pilot search**.

[0067] This digital signal bearing medium may comprise, for example, RAM or

an
ASIC (neither shown) contained in a communications network. Alternatively, the instructions may be contained in another signal bearing medium, such as a magnetic data storage medium, directly or indirectly accessible to the digital signal processing unit. In an illustrative embodiment of the invention, the machine-readable instructions may comprise lines of compiled computer code, such as C, C++, or Java, or other suitable coding language commonly used by those skilled in the programming arts.

Other Embodiments

[0068] While there have been shown what are presently considered to be exemplary embodiments of the invention, it will be apparent to those skilled in the art that various changes and modifications can be made without departing from the scope of the invention as defined by the appended claims.

CLAIMS:

What is claimed is:

1. A method for conducting a **pilot signal search in a wireless** communications
network, comprising: determining the location of a **mobile** station within the network; utilizing said location of said **mobile** station, search window sizes, and parameter information to minimize the **search time required for searching all the pilots** identified in a pilot set; and **searching for all pilots** in said pilot set.

2. The method in accordance with claim 1, wherein the location of the **mobile** station is tracked within the communications network.

3. The method in accordance with claim 1, further comprising the step of: utilizing signal multipath effects in conjunction with said location of said **mobile** station to determine search window sizes.

4. The method in accordance with claim 3, further comprising the steps of: storing search window sizes relative to the respective location of the **mobile** station within a cell; and determining search parameters using the stored search window size for a known location of a **mobile** station.

5. The method in accordance with claim 4, wherein the stored location of the **mobile** station is stored in a three dimensional table.

6. An article of manufacture embodying a program of machine-readable instructions executable by a digital signal processing apparatus to perform a method for conducting a **pilot signal search in a wireless** communications network, said readable instructions comprising: determining the location of a **mobile** station within the network; utilizing said location of said **mobile** station, search window sizes, and parameter information to minimize the **search time required for searching all the pilots** identified in a pilot set; and **searching for all pilots** in said pilot set.

7. The article of manufacture in accordance with claim 6, the readable instructions further comprising: utilizing signal multipath effects in conjunction with said location of said **mobile** station to determine search window sizes.

8. The article of manufacture in accordance with claim 7, further comprising: storing search window sizes relative to the respective location of the **mobile** station within a cell; and determining search parameters using the stored search window size for a known location of a **mobile** station.

9. An apparatus for conducting a **pilot signal search in a wireless** communications network, comprising: at least one base station including a first digital signal processing unit, wherein said at least one base station transmits a pilot signal, and wherein said first digital signal processing unit can be used in determining the location of a **mobile** station within the communications network; at least one **mobile** station including a **second** digital signal processing unit, wherein the at least one **mobile** station is communicatively coupled with the at least one base station, and wherein the **second** digital signal processing unit can use the location of a **mobile** station, search window sizes, and parameter information to minimize the **search time required for searching all pilot** signals identified in a pilot set.

10. The apparatus in accordance with claim 9, wherein a selected base station of the at least one base stations communicates the search window size and parameter information using a traffic channel to the at least one **mobile** station.

11. An apparatus for conducting a **pilot signal search in a wireless** communications network, comprising: a first means for determining the location of a **mobile** station within the communications network; and a **second** means, communicatively coupled with said first means, for using the location of the **mobile** station, search window sizes, and parameter information to minimize the **search time required for searching all pilot** signals identified in a pilot set.

er element is employed to measure the signal arrival **times** for the base stations not in the active set. Initially, the searcher element processes the received signal and searches for strong multipaths. This can be achieved by **searching for pilots** in the received signal at various PN offsets. A list of potential pilots for the inactive base stations can then be compiled. This list includes identified pilots that exceed a particular signal quality.

(44) To measure the signal arrival **times, the searcher element can synchronize to each pilot** in the list. Since the PN offset of the **pilot was previously determined, the searcher element can synchronize to the pilot** in a shorter **time** period, which may be dictated in part by the amount of movement in the pilot since it was last processed. For each synchronized **pilot, the searcher** element measures the signal arrival **time**. At approximately the same **time,** the assigned finger processors are also operated to measure the signal arrival **times** for other base stations (in the active set). Again, the signal arrival **times** for all base stations of interest can be measured within as short a **time** period as possible to minimize the effects of movement (if any) by the remote terminal. The measured arrival **times** from the searcher element and the finger processors are subsequently processed in the manner described above.

(45) The measurements of the signal arrival times by the searcher element can be scheduled. In the time period between updates of the reference oscillator, the signal arrival times for a number of base stations can be measured sequentially. For example, the pilots from these base stations can be processed in a particular order determined to provide good results.

(46) The list of potential pilots can be traversed such that pilots from different base stations are processed sequentially. In one implementation, the earliest arriving pilot for each base station is processed in sequential order. For example, the earliest arriving pilot for a first base station is processed first, the earliest arriving pilot for a second base station is processed next, and so on. In another implementation, the pilot with the best signal quality for each base station is processed in sequential order. For example, the (best signal quality) pilot for the first base station is processed first, the (best signal quality) pilot for the second base station is processed next, and so on. Different processing orders can also be contemplated and are within the scope of the invention.

(47) The signal arrival **times** can be measured by the **searcher element based on the pilots,** as described above. Alternatively, the signal arrival **times** can be measured by processing the **radio** frames. In another embodiment, one or more

lephone's location. Times-of-arrivals and/or signal strength measurements of other signals may also be used to estimate a mobile-telephone's location.

(7) To increase the accuracy of the estimate, one embodiment of the present invention uses forward link power control. Advantageously, the use of forward link power control requires minimal changes to the network side of existing wireless communication standards and no changes to the mobile-telephone side,
thus making it easier to implement. Referring to FIGS. 5 and 5a, a flowchart 40 illustrates the steps for accurately estimating a location of a mobile-telephone in accordance with one embodiment of the present invention. In step 400, a serving base station, i.e., base station with direct control of call processing for the mobile-telephone, provides the mobile-telephone with a neighbor list indicating the timing offsets associated with the pilot signal of the serving base station and base stations adjacent to the serving base stations. For example, as shown back in FIG. 2, if base station 14-1 is the serving base station for the mobile-telephone 16, then the neighbor list would at least indicate the offsets associated with the serving base station 14-1 and the adjacent base stations 14-3 and 14-4, i.e., offsets 0, 2 and 3. In IS-95A, the neighbor list is provided via a paging signal (i.e., forward link signal transmitted over a paging channel) from the serving base station.

(8) In step 410, the serving base station starts transmitting a pilot signal at a time corresponding to its associated offset. In step 415, the mobile-telephone monitors a search window for the serving base station's pilot signal using the offset indicated on the neighbor list. Specifically, the mobile-telephone uses the offsets in the neighbor list to approximate a search window during which the mobile-telephone should expect to detect the serving base station's pilot signal. For example, if the neighbor list indicates offset 0 (for the serving base station 14-1), then the mobile-telephone monitors for the serving base station's pilot signal during a search window defined by a predetermined time before offset 0 and a predetermined time after offset 0.

(9) Note that step 415 (and other subsequent steps) requires the mobile-telephone and/or the neighbor base stations to be time synchronized--that is, the time at the mobile-telephone and at the serving (and adjacent) base station should have some known relationship with each other. In one embodiment, the time at the mobile-telephone and serving (and adjacent) base station are synchronized using a c

sized to correspond
to the worst case scenarios. That is, they are sized to correspond to a mobile located at the greatest distance from the base station but within the cell.

[0030] On the paging or traffic channels, the mobile centers its search window for each pilot in the neighbor set around the pilot's PN sequence offset, using timing established by the mobile's time reference. The mobile's time reference is defined as the earliest arrived and usable path. The worst case scenario determines the search window size. For example, FIG. 1 shows four adjacent cells 102, 104, 106, and 108 in a wireless system 100, each having a pilot designated PN1, PN2, PN3, and PN4, respectively. The search window size for pilot PN1 is determined based on a mobile located at point A. However, the same
search window is used even if the mobile is at point B. This results in a waste of valuable searcher resources since it does not consider the location of the mobile within cell 104. If the mobile is at point B, the search window should be reduced in size relative to the search window required for a mobile located at point A.

[0031] D. Location Methods

[0032] Many techniques are being considered to provide for automatic location capability for mobiles. One technique involves measuring the time difference of arrival of signals from a number of cell sites. These sign

pilot in the
Candidate Frequency Search Set around the pilot's PN sequence offset using timing defined by the mobile's time reference.

[0028] C. Time to Search

[0029] Each phone manufacturer has its own way of implementing a search strategy. In all strategies, the time to search a specific pilot depends on the window size and the hardware of the searcher. Given certain hardware, the time to search a pilot is linearly proportional to the search window size. Reducing the search window size will result in a substantial reduction in searching time. Using current searching procedures, the window sizes are mostly determined by the size of the coverage area of a given cell. A cell is the geographical area covered by a base station for communication with a mobile. Four such cells are shown in FIG. 1. Regardless of the location of the mobile in the serving cell, current search windows are sized to correspond to the worst case scenarios. That is, they are sized to correspond to a mobile located at the greatest distance from the base station but within the cell.

[0030] On the paging or traffic channels, the mobile centers its search window for each pilot in the neighbor set around the pilot's PN sequence offset, using timing established by the mobile's time reference. The mobile's time r

window, typically of a certain number of chips, in which to look for the first chip of the GPS signal. This window is often referred to as the code phase search window.

(14) It takes a significant amount of processor power to determine the local GPS time at which the first chip is received. Performing this determination centrally, for example, in the GPS receiver of PDE 150, using the processor located in the PDE, and then providing the resulting search window to the mobile terminals allows the mobile terminals to use much smaller processors and still be able to fairly quickly determine when the first chip of a GPS signal is due to arrive at the mobile terminals. The mobile terminal then uses the search window to determine when the first chips of the various GPS signals arrive at the mobile terminal, which it then uses to determine GPS obtained location information. The GPS obtained location information is used by the mobile terminal or by the PDE (or another part of the wireless communication system) to estimate the mobile terminal's location. (Note that the above description addresses only the detection of the GPS signal in the time domain, assuming the Doppler shift and frequency are known.)

(15) However, there are several factors that make the search window at GPS receiver 160 of the PDE not as accurate at the mobile terminals as it is at GPS receiver 160. The search window should be adjusted to accommodate for two of the important factors before the mobile terminal uses the search window. The first of these factors is that the mobile terminal is not located at the same location as GPS receiver 160. Therefore, the travel time of the GPS signal to the mobile terminal will be different than the travel time to the GPS receiver 160, which will change the time at

that uses AGPS, PDE 150 can also include GPS receiver 160.

(4) PDE 150 can use any of a number of geo-location techniques that are known
for estimating the location of a mobile terminal. A typical one of these geo-location techniques is to estimate and use a round-trip delay--the time it takes a signal to travel from base station 116 to mobile terminal 120 and back--to determine the one way delay--the time it takes to travel between the mobile terminal and the base station. One way delay is calculated by subtracting the transmitting and receiving time delays from the round trip delay and dividing the result by two. The transmitting and receiving time delays can be determined by calibrating the base station. The one way delay is multiplied by the speed of light to produce the distance of mobile terminal 120 from base station 116. This distance and the knowledge that mobile terminal is located in sector 106a are then used to determine the location of mobile terminal 120. This typically allows the estimation of the location of mobile terminal 120 with an accuracy of between 200 m and 1500 m, depending on the size of cell 106.

(5) Other geo-location techniques can be used instead of, or in addition to, round trip delay to estimate the location of the mobile terminal. For example, the location of mobile terminal 140 can be estimated using such techniques known in the art as time-difference-of-arrival, angle-difference-of-arrival, or angle-of-arrival. Some of these geo-location techniques can be used regardless of the number of base stations visible to the mobile terminal whi

ocation
and the desired accuracy of the estimation. If AGPS is not to be used, the answer in step 325 is NO, then is step 330 PDE 250 makes the location of the mobile terminal available to the services of the wireless communication system that would use it, such as, for example, the emergency 911 applications, or location based billing.

(31) If AGPS is to be used, the answer in step 325 is YES, then is step 335 the PDE uses the location of the mobile terminal to determine the one way delay between the base station and the mobile terminal. As described above, the PDE uses the location of the mobile terminal and the one way delay to adjust the search window, step 340, and provides the search window to the mobile terminal,
step 345. The mobile terminal then uses the search window to determine when the first chips of the various GPS signals arrive at the mobile terminal, which it then uses to determine its location.

(32) It will be recalled that the sequence of steps just described is carried out when the determination of whether there are enough base stations visible to the mobile terminal to be able to use only forward-link geo-location techniques to determine the location of the mobile terminal, at step 305, resulted in an answer of YES. If on the other hand this determination resulted in an answer of NO, such as for example for mobile terminals 120 and 130, the process then proceeds to step 360. (For ease of reference steps 360 through 370 are first described for mobile terminal 120 and then for mobile terminal 130.) At step 360 the PDE selects a geo-location technique, or combination of geo-location techniques, at least one of which is a reverse-link geo-locatio

TS(28
7/16) and base 357 receives it at time TS(29 7/16), with propagation and receive (i.e., antenna to detector) delays of .DELTA.P2, .DELTA.rB1 and .DELTA.P3, .DELTA.rB2, respectively. Similar repeat measurements are also performed, for example base 301 receiving chip 150 at time TS(78 7/16), the subscriber having controlled the output time of chip 150 to TR(74 1/16), i.e., precisely 50 chips (40,700 ns) later.

(21) After a predetermined number of pairs are determined, the chip/time information and response signal information are forwarded to the location searcher 361 or 367. The searcher 361 or 367 then calculates the propagation delays, e.g., .DELTA.P1-.DELTA.P3, using the other known information. In this case, let the calibrated base delays .DELTA.tB1, .DELTA.rB1 and .DELTA.rB2 be
5/32, 3/32 and 3/32 chips. Because .DELTA.P1 is essentially the same as .DELTA.P2, then ##EQU1## Thus, .DELTA.P1 is 2 chips, or 1628 ns, and the propagation path length is about 488 m (+/-30 m at 100 ns total uncertainty). Once .DELTA.P1 is known, .DELTA.P3 can similarly be calculated, yielding in the
illustrated case a time of 3 chips and distance of 733 m. By calculating the propagation path length for at least three receivers, and retrieving the location information on the receiving bases (e.g., from databases 362 or 368) the position of the subscriber may be determined by calculating the unique point (or small region of highest probability) at which the respective propagation paths can all intersect. The process is repeated for each time/chip set. Each calculated point (or centroid of the probably region) is then used in determining the subscriber location, e.g. most simply by averaging, although any suitable process for fitting determining a most likely point/region from multiple points/regions can be used. The location of the most likely point/region is preferably stored in the user profile database 369 of HLR 366. Additionally, the entire process can be repeated after one or more further periods of time, on the order of seconds or minutes, with the plural most likely regions being used to determine a speed and direction of travel of the subscriber; if an accurate enough subscriber clock is being used so drift is under 50 ns for an extended period of multiple minutes (i.e., the subscriber clock's offset from the system time is known for that period), repeated detections at the bases could be performed without the need to repeat the request signal). Finally, the determined location, and travel speed/direction, are forwarded to the originally requesting entity, e.g. to operator 370 or via PSTN 375.

(22) A particular advantage of using the active location process over the inactive one is that, if desired, three-dimensional information can be more

gorithm with both types of
variables may be expressed as follows:

(3) If [E.sub.A (t.sub.i)-E.sub.B (t.sub.i)]+[(M.times.(POS.sub.A (t.sub.i) -POS.sub.A (t.sub.i-1)).times.Ee.sub.A (t.sub.i)/E.sub.A (t.sub.i)) -(N.times.(POS.sub.B (t.sub.i)-POS.sub.B (t.sub.i-1)) .times.Ee.sub.B (t.sub.i)/E.sub.B (t.sub.i))]<H, then initiate idle handoff,

(9) where E.sub.A (t.sub.i) and E.sub.B (t.sub.i) are the signal strengths in dB of the active pilot channel and base station B pilot channel respectively at pilot sample time t.sub.i, POS.sub.A (t.sub.i) and POS.sub.A (t.sub.-1) are the time or phase offsets (i.e., positions) associated with the earliest arriving usable multipath signals received by the mobile station from that active base ~~station A at pilot sample times t.sub.i and~~ t.sub.i-1 respectively, t.sub.i-1 denoting a previous mobile~~-station~~ sample time, POS.sub.B (t.sub.i) and POS.sub.B (t.sub.i-1) are the ~~time or phase offsets (i.e.,~~ positions) associated with the earliest ~~arriving usable multipath signals~~ received by the mobile station from base station B at pilot sample times t.sub.i and t.sub.i-1, respectively, Ee.sub.A (t.sub.i) and Ee.sub.B (t.sub.i) are the signal strengths in dB of the earliest arriving usable multipath pilot channel signal from the active base station A and base station B respectively at pilot sample time t.sub.i, and M, N and H are design parameters.

(10) Design parameter H is the same as in the original handoff algorithm. Design parameters M and N however, allow system engineers to further control when an idle handoff will be initiated by affecting the weight given to each position term in the improved algorithm. For instance, if system engineers seek to have each position term equally affect the decision whether to initiate an idle handoff, then M would be set equal to N. On the other hand, if system engineers seek to have the position relative to the active base station exert more influence on the decision, then M would be set greater tha

g channel. The third set is the remaining set, which is comprised of all the possible pilot offsets in the current CDMA frequency assignment but excluding the members of the active and neighbor sets. The mobile station typically supports a neighbor set of at least 20 pilot offsets in size.

(4) The base station also specifies, in addition to the pilot offsets, search windows for each of the pilot sets. In other words, the base station specifies a range of PN offsets or a window in which the mobile station is to search for the multipath components of each pilot in each of the sets. Once the mobile has detected a pilot with a sufficiently strong signal and begins tracking that pilot, it will make a record for each multipath component of the pilot that it is receiving and continue searching the PN space for other pilots in the neighbor or remaining sets. In subsequent searches of the PN space, the mobile will center the search window of its scanning receiver around the earliest arriving multipath component of each pilot for which it has made a record. The mobile station measures the total strength, E.sub.X, of each pilot X in a given search window by adding the ratios of received pilot energy per chip, E.sub.Xc, to total received spectral density (noise and signals), I.sub.Xo, of at most k usable multipath components, where k is the number of demodulating elements supported by the mobile. A usable multipath component is one that is sufficiently strong to be tracked, and that if used, would not cause prohibitive frame errors or power control bit errors. The arrival time, T.sub.i, for each pilot X being searched is the time of occurrence, as measured at the mobile station antenna connector, of the earliest arriving usable multipath component of the pilot, and is measured relative to the time reference of the mobile station in units of PN chips. Hence, the phase or PN offset of the received pilot multipath component corresponds to the arrival time of that component. The mobile computes pilot phase, .phi..sub.x, from the following relationship:

(1) .phi..sub.x =(T.sub.i +64*PILOT_PN)mod2.sup.15,

(5) where PILOT_PN is the PN sequence offset index of the pilot X being searched.

(6) Also noted above was the conventional algorithm used in current wireless communications systems for determining whether an idle handoff should be performed. Namely, whenever the mobile station determines that the signal strength of a pilot channel emitted by a nearby base station is sufficiently stronger than that of the active pilot channel signal an idle handoff is initiated. This energy compariso

ions
of said first wireless service provider.

47. An apparatus for locating a first mobile station, wherein the first mobile station communicates via wireless signals with a first wireless network infrastructure having: a plurality of spaced apart base stations for wireless communication with said first mobile station, wherein at least one of said first mobile station and said first wireless network infrastructure has a capability for obtaining a plurality of multipath measurements for one of: one or more forward transmissions to said first mobile station, and one or more reverse transmissions from said first mobile station to said first wireless network infrastructure, and wherein said multipath measurements are derived from both fixed clutter and variable clutter, comprising: [wherein said mobile switching center also communicates with said plurality of base stations for receiving measurements of said radio signals, said measurements including: (i) first measurements of said radio signals received by said first mobile station in said forward radio bandwidth, and (ii) second measurements of said radio signals transmitted by said first mobile station in said reverse radio bandwidth;]a mobile station location determining system for locating said first mobile station, wherein said location determining system is capable of transforming [receives said first and second] values indicative of said multipath measurements for at least one of said forward transmissions and said reverse transmissions, wherein said transformed values have an enhanced dependence on multipath measurements derived from fixed clutter as compared to
multipath measurements derived from variable clutter; wherein said mobile station location determining system includes at least one wireless location determining model for estimating a location of said first mobile station, said at least one model uses one or more of said transformed values; a means for transmitting, to said location determining system, said values indicative of said multipath measurements; a means for outputting, from said location determining system, a resulting location estimate of said first mobile station.

48. An apparatus for locating a mobile station as claimed in claim 47, further including a means for requesting data related to additional radio signals between said first mobile station and at least a second wireless network infrastructure different from said first wireless network infrastructure.

49. An apparatus for locating a mobile station, comprising: a wireless network infrastructure for communicating with a plurality of mobile stations, each said mobile station for transmitting and receiving wireless signals, wherein said wireless signals are received in a forward bandwidth and said wireless signals are transmitted in a different reverse bandwidth, and, said wireless network

e (MAC) control parameter sent to the mobile station 140 via the air (i.e., wireless) interface from a BS 122, with either the CMAC or VMAC command (as one knowledgeable in CDMA standards will understand). The MAC can take on one of eight values 0 through 7, which effect a closed loop to raise or lower the power correction. The transmit amplifier 516 may utilize one of three transmit power classes when transmitting within a transmitted power control group in the 800-900 MHZ cellular band: class I (1 to 8 dBW), class II (-3 to 4 dBW), or class III (-7 to 0 dBW), for a closed-loop range of about "32 dB. In the PCS 1.8-1.9 GHz band five classes are defined: class I (-2 to 3 dBW), class II (-7 to 0 dBW), class III (-12 to -3 dBW), class IV (-17 to -6 dBW), class V (-22 to -9 dBW), for a closed-loop range of about "40 dB. The mobile station 140 power class and transmit power level for a communicating mobile station 140 is known to the wireless infrastructure network, and may be utilized for location estimation, as is described hereinbelow.

[0161] The digitized IF signal may contain the signals from several telephone calls together with the pilot channels and multipath delayed signals from each of several pilot channels. Searcher receiver 526, under control of control processor 534, continuously scans the time domain around the nominal time delay offsets of pilot channels contained within the active, candidate, neighboring and remaining sets of pilot channels. The initial sets of pilot channels and a defined search window size for each set are provided by a control message from a BS 122 via the air interface to the mobile station 140. The searcher receiver 526 measures the strength of any reception of a desired waveform at times other than the nominal time and measures each pilot channel's arrival time relative to each pilot's PN sequence offset value. Receiver 526 also compares signal strength in the received signals. Receiver 526 provides a signal strength signal to control processor 534 indicative of the strongest signals and relative time relationships.

[0162] Control processor 534 provides signals to control digital data receivers 520, 522 and 524 such that each of these receivers processes a different one of the strongest signals. Note, as one skilled in the art will understand, the strongest signal, or finger, may not be the signal of shortest arrival time, but rather may be a reflected, and therefore delayed, signal (such reflected denoted collectively as "multipath"). Data receivers 520, 522 and 524 may track and process multipath signals from the same forward channel pilot channel offset or from a different forward channel pilot offset. In the case where a different pilot channel offset signal is of greater strength than the current cell site (or more specifically the current base station 122) pilot channel

the mobile station
control processor provides, or would interface with a function emulating mobile termination 0 or 2 services at the R.sub.m network reference point. The L-API then provides, or would interface with a function emulating the physical interface connecting a data circuit-terminating equipment (ICE) to the PSTN at the W network reference point, in communication with the PSTN, which is also in communication with reference point Ai, which is in communication with reference point U.sub.m, which is in turn in communication with reference point R.sub.m. An advantage of this embodiment is that no ASIC or circuit board modifications are needed in the mobile station.

[0179] The ANSI standards J-008 and IS-95 provide several means for the base station 122 to establish and to extend the search window size that the mobile station 140 should use in its scanning process, and to identify further pilots. For location purposes, either existing standard parameters can be extended, or a location message request from the Base station can inform the searcher receiver of the mobile station to extend its search range, as necessary, to capture all relevant base station pilots and their multipath fingers, in order to complete the location measurement sample.

[0180] The search performance criteria defined in ANSI IS-98, Recommended Minimum Performance Standards for Dual Mode, can be increased as appropriate to
accommodate a larger set of potentially detectable base stations, including Location Base stations and Mobile Base stations. Additionally the search window table size for various search window values must be increased to accommodate new pilot channel pn-offsets associated with Location Base Stations
and Mobile Base stations.

[0181] Existing standard parameters include, for example using the In-traffic System Parameters Message, the values SRCH_WIN_A (for active and candidate
set), SRCH_WIN_N (for neighboring set), and SRCH_SIN_R (for remaining set) can
be used to cause the searcher receiver to increase its search area to detect and thus measure as many pilots as can be detected in the area. Extending the range of T_ADD and T_DROP parameters can also be used to facilitate the mobile
to retain data on additional pilots in the area. The extended neighbor list message is used to inform the mobile station of the necessary characteristics of neighboring pilot signals. For example if location base stations are used on a different frequency assignment, and/or utilize unique, non-public pilot PN

receiver of FIG. 5 includes a searcher 510, a plurality of RAKE fingers 520 and a combiner 530 which operate in a manner similar to that set forth above with respect to FIG. 4. The RAKE receiver of the present embodiment also comprises a motion detector 540.

(22) When the mobile station is receiving a transmitted signal, an estimate of the mobile station's velocity is determined. This estimate is determined by, for example, estimating the Doppler frequency of the different multipath components, tracking the timing differences of the different multipath components, or by using the Global Positioning System (GPS). When the velocity estimate is determined by estimating the Doppler frequency of the different multipath components, one skilled in the art will appreciate that such an estimation is performed by the RAKE fingers wherein each finger's path variation could be considered individually or, in the alternative, the estimate could be reflective of the majority.

(23) Irrespective of the manner in which the velocity estimate is made, the searcher 310 uses this estimate to optimize its duty cycle. For example, one skilled in the art will appreciate that at low velocities, the variation of the multipath rays is minimal. As will be more apparent below, the minimal variation in the multipath rays allows for the time in which the searcher operates to be minimized. By minimizing the operation of the searcher, a reduction of the power consumed by the mobile station can be achieved. In the alternative, large variations indi

11. A mobile station for use in a wireless communication system comprising a processor which determines search window limitations for one or more sectors due to cell coverage area and due to the mobile station dynamics, wherein the mobile station searches for an earliest pilot phase offsets of the sectors using the determined search windows.
12. The mobile station of Claim 11, wherein the processor determines search window offsets for each of the one
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or more sectors based on t=he relative phase offset between pilots of sectors.
13. The mobile station of Claim 12, wherein the processor further determines search window limitations by determining an earliest point in time of the window as earlier than the latest of the line-of-sight or earliest path times from a set of sectors by a cell size based factor or speed based factor.
14. The mobile station of Claim 12, wherein the processor further determines search window limitations by determining a latest point in time of the window as later than the earliest of the line-of-sight or earliest path times from a set of sectors by a cell size based factor or speed based factor.
15. The mobile station of Claim 11, wherein the search window size is set asymmetrically from an early and a late side.
16. The mobile station of Claim 11, wherein an early side of the search window is set based on cell size and speed of the mobile station.
17. The mobile station of Claim 11, wherein a later side of the search window is set based on a speed of the mobile station.
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18. The mobile station of Claim 11, wherein the mobile station receives cell size based limitations.
19. The mobile station of Claim 18, wherein the cell size based limitations are embedded in overheads or other messages.
20. The mobile station of Claim 11, wherein the results of phase measurements are input to position location algorithms.
21. A wireless communication system which tracks earliest pilot phase offsets for geo-location determination comprising:
one or more base stations, each of the one or more base stations serving a cell divided into one or more sectors; and
a mobile station which determines search window limitations for the one or more sectors due to the cell coverage area and due to mobile station dynamics, wherein the mobile station searches for

the earliest pilot phase offsets of the one or more sectors using the determined search windows.

22. The wireless communication system of Claim 21, wherein the mobile station determines search window offsets for each of the one or more sectors based on the relative phase offset between pilots of sectors.

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23. The wireless communication system of Claim 22, wherein the mobile station further determines search window limitations by determining an earliest point in time of the window as earlier than the latest of the line-of-sight or earliest path times from a set of sectors by a cell size based factor or speed based factor.

24. The wireless communication system of Claim 22, wherein the mobile station further determines search window limitations by determining a latest point in time of the window as later than the earliest of the line-of-sight or earliest path times from a set of sectors by a cell size based factor or speed based factor.

25. The wireless communication system of Claim 21, wherein the search window size is set asymmetrically from an early and a late side.

26. The wireless communication system of Claim 21, wherein an early side of the search window is set based on cell size and speed of the mobile station.

27. The wireless communication system of Claim 21, wherein a later side of the search window is set based on a speed of the mobile station.

28. The wireless communication system of Claim 21, wherein the mobile station receives cell size based limitations.

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29. The wireless communication system of Claim 28, wherein the cell size based limitations are embedded in overheads or other messages.

30. The wireless communication system of Claim 21, wherein the results of phase measurements are input to position location algorithms.

31. A method of improving geo-location measurements in a wireless communication system comprising:

computing a set. of parameters;

transmitting the set of parameters to a mobile station; and

modifying a geo--location search based on the set of parameters.

32. The method of Claim 31, further comprising determining the speed of the mobile station.

33. The method of Claim 31, further comprising using infrastructure location information to determine the parameters.
34. The method of Claim 33, further comprising dividing the location information into cell sectors.
35. The method of Claim 31, further comprising identifying each cell sector by number.
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36. The method of Claim 31, further comprising modifying search parameters when performing geo-location searches.
37. A method for modifying geo-location searches in a wireless communication system comprising:
determining a set of parameters; and
modifying a search window size and offset based on the set of parameters.
38. The method of Claim 37, further comprising computing the speed of the mobile station to obtain the set of parameters.
39. The method of Claim 38, further comprising determining infrastructure information to estimate neighbor timing data.
40. The method of Claim 29, further comprising dividing the cell into sectors, wherein each sector has specific neighbor timing information.
41. The method of Claim 37, further comprising computing the set of parameters at the base station.
42. The method of Claim 37, further comprising detecting the line-of-sight path to determine the geo-location information.
43. The method of Claim 37, further comprising transmitting the set of parameters to a mobile station.
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44. The method of Claim 43, further comprising modifying a search window based on the set of parameters when performing a geo-location search.
45. A wireless communication system comprising:
a plurality of base stations which calculate a set of parameters for geo-location searches; and
a mobile station which performs geo-location searches with one or more of the plurality of base stations, wherein the mobile station receives the parameter set from the plurality of base stations and modifies the geo-location searches based on the parameter set.
46. The wireless communication system of Claim 45, wherein the mobile station further determines search window limitations by determining an earliest point in time of the window as earlier than the latest of the line-of-sight or earliest path times from

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless -
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

2. Claims 1-4 are rejected under 35 U.S.C. 102(b) as being anticipated by Buford et al..

Regarding claims 1 and 2, Buford et al. discloses a method (fig. 7) of tracking earliest pilot phase offsets for geo-location determination (col. 1 lines 50-60,col. 3 lines 15-38 and col. 6 lines 7-23) comprising: determining search window limitations (i.e. the difference tb21 and tb31 in reception time)(col. 6 lines 7-20) for one or more sectors (i.e. sectors or branches, fig. 13 numbers 1350,1360) due to cell coverage area (col. 6 lines 7-23) and due to mobile station dynamics (distance to base station)(col. 3 lines 15-38 and col. 6 lines 7-23); and searching for earliest pilot phase offsets (earliest time) of the sectors (branches) using the determined search windows (col. 6 lines 7-23).

Regarding claim 3, Buford et al. discloses determining an earliest point in time of the window as earliest path times from a set of sectors (branches) by a cell size based factor (the mobile distance from the base station)(col. 6 lines 7-23).

Regarding claim 4, Buford et al. discloses earliest times from a sect of sectors by a cell size base factor (the mobile distance from the base station)(col. 6 lines 7-23).

Regarding claim 8, Buford et al. discloses transmitting cell size based limitations (geographic coordinates) to a mobile station (col. 6 lines 26-41).

Regarding claim 9, Buford et al. discloses embedding the cell size based limitations in overheads message (inherent, since the geographic coordinates are sent from a base station to the mobile station, taught in col. 6 lines 26-41).

Regarding claim 10, Buford et al. discloses using results of phase measurements in position location algorithms (col. 6 lines 7-41).

Claim Rejections - 35 USC § 103

1. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

2. Claim 5 is rejected under 35 U.S.C. 103(a) as being unpatentable over Buford et al. in view of.

5. The method of Claim 1, further comprising setting the search window size asymmetrically from an early and a late side.

6. The method of Claim 1, further comprising setting an early side of the search window based on cell size and speed of a mobile station.

7. The method of Claim 1, further comprising setting a later side of the search window based on a speed of a mobile station.